AD-A124 147 PLANNING AND PRIORITIZING PEOPLE-RELATED RESEARCH AND DEVELOPMENT IN THE NAVY(U) NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO CA L M DOHERTY ET AL. 1/1

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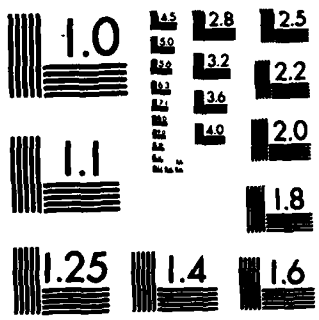

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NPRDC Special Report 83-12 January 1983

PLANNING AND PRIORITIZING PEOPLE-RELATED RESEARCH AND DEVELOPMENT IN THE NAVY

Linda M. Doherty
Harry R. Seymour

Reviewed by
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NPRDC SR 83-12

2. GOVT ACCESSION NO.
AD-A124147

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
PLANNING AND PRIORITIZING PEOPLE-RELATED RESEARCH AND DEVELOPMENT IN THE NAVY

5. TYPE OF REPORT & PERIOD COVERED
Special Report
FY81-82

6. PERFORMING ORG. REPORT NUMBER
3-82-7

7. AUTHOR(s)
Linda M. Doherty
Harry R. Seymour

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Navy Personnel Research and Development Center
San Diego, California 92152

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Navy Personnel Research and Development Center
San Diego, California 92152

12. REPORT DATE
January 1983

13. NUMBER OF PAGES
58

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Prioritization of R&D
R&D planning
Rankings of incomplete data
Ranking procedures

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a quantitative procedure for prioritizing people-related R&D requirements in the Navy and initiatives taken to reduce R&D program fragmentation.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

The procedure for prioritizing R&D requirements described in this report was developed under project number PO53003 (Prioritization of R&D) in response to a request by the Deputy Chief of Naval Operations (OP-01). This procedure, which produces overall rankings from incomplete initial ratings, can be used by R&D managers to evaluate requirements and related projects. Initiatives for reducing R&D program fragmentation also are discussed.

JAMES F. KELLY, JR.
Commanding Officer

JAMES W. TWEEDDALE
Technical Director

[illegible]

R&D Program Fragmentation

The following initiatives have been taken to reduce the fragmentation problem and aid in coordination efforts:

1. [illegible] has (a) established a Planning and Appraisal Office to [illegible] ... (c) identifying areas where R&D plans for [illegible] should be developed.

2. The Director of [illegible] has recommended that the priority of [illegible]

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INTRODUCTION

Problem

There are two major problems in managing the Navy's people-related research and development (R&D) program. The first is how to determine which R&D projects should be undertaken and in what priority order. The second is how to reduce R&D program fragmentation.

Navy R&D managers are confronted with more stated requirements to conduct R&D than they have resources available. Often, they have to decide how to allocate resources to R&D projects without having complete information about the projects and how they relate to requirements. If R&D projects respond to an immediate operational problem but overlook long-range R&D requirements, the result is an overall R&D program that does not respond to critical issues in a far-sighted integrated fashion.

The fragmentation problem is due to a variety of factors. For example, since the budget process that categorizes and controls research dollars is oriented toward hardware acquisitions, the emerging terminology, definitions, connotations, guidelines, and practices are not conducive to planning and managing people-related R&D. Also, the formal and informal reporting chains are cumbersome and too complex to address major issues in an integrated manner.

Objective

This report describes (1) a system for prioritizing people-related R&D requirements developed at the Navy Personnel Research and Development Center (NAVPERSRANDCEN) and (2) initiatives taken to reduce R&D program fragmentation.

PRIORITIZATION OF R&D PRODUCTS

Background

There are several problems, both external and internal to the R&D organizations, in developing a system of prioritizing R&D requirements. Some of these problems are described below.

1. The term "requirements" in an R&D task description sometimes refers to operational requirements or people-related problems in the Navy. At other times, it refers to taskings or requests that a specific R&D project be conducted. Because of this ambiguity, stated "requirements" referring to operational requirements may not be directly translatable into R&D questions. In many cases, the questions to be addressed or the problems to be solved would be better addressed by other approaches (e.g., management improvements or policy changes). All Navy requirements are not necessarily amenable to R&D solutions.

2. Prioritizing R&D projects in terms of specific R&D requirements assumes that an extensive pool of requirements is available. Thus, it is important that all relevant sources be queried regarding those requirements. R&D requirements are dynamic, representing a constantly changing state of the world, and must be updated frequently. Further, since the scope of such requirements varies widely, they must be matched on their scope before they are prioritized.

3. The process for prioritizing R&D requirements must be dynamic to permit adaptation to changes that are beyond the control of R&D managers. For example, during 1978-79, when first-term enlisted attrition was a major problem for the services, considerable R&D effort was directed at requirements to alleviate the large personnel losses. When the supply of individuals entering the all-volunteer force increased, the attrition problem was reduced, due to a natural selection process occurring at time of entry and to shifts in economic conditions. Better qualified individuals were being accessioned into the Navy and they tended to remain until the end of their obligated service. R&D requirements associated with reducing attrition were no longer considered as important; it had been ameliorated, at least in the short term, by a series of economic and social events.

Prioritization Procedure

NAVPERSRANDCEN developed an empirical approach for prioritizing POM-84 Manpower, Personnel, Training, and Human Factors Engineering (MPT&HFE) project submissions. This approach, which was modified from that used to rank POM-83 project submissions, was further tested by applying it to a list of NAVPERSRANDCEN R&D requirements. This approach is described below.

POM-83 Prioritization Procedure

A panel of seven judges, representing high level management from the Deputy Chief of Naval Operations for Manpower, Personnel, and Training (MPT) (OP-01) (N=2) and NAVPERSRANDCEN (N=5) identified the following criteria for prioritizing R&D projects at a July 1980 working session hosted by NAVPERSRANDCEN:

1. Importance/necessity. Value of the project to the Navy.

2. Payoff. Value of the project's return to the Navy weighted against the resources required for R&D and implementation.

3. Timeliness. Urgency to complete now, political requirements, etc.

4. Probability of success. Probability that the effort would be successful (not to include an assessment of the likelihood that the results will be implemented).

5. Validity as R&D. Whether project is a first demonstration or development of new technology.

6. Link to other work. Other planned or approved work is dependent upon completion.

Next, the judges rated each project in NAVPERSRANDCEN's POM-83 MPT&HFE submittal on each criterion using a scale of 1 (low) to 10 (high). Since this was a first effort in quantitatively prioritizing R&D projects, several problems were encountered, including the following:

1. Individual projects were first organized around arbitrarily designated end-product areas. These categories require broadening and updating.

2. Since the projects were rated independently on each criterion, they were not ranked or compared.

3. In forming an overall evaluation of each project, equal weights were assigned to all criteria.

4. The process was time consuming because the rankings required a group consensus.

POM-84 Prioritization Procedure

The POM-83 R&D prioritization procedure was improved by (1) increasing the number of judges to 13 by including NAVPERSRANDCEN program directors, (2) reducing the rating time required by producing a rating format and project descriptions, and (3) applying a quantitative method that permitted projects to be compared, and removed the requirement that all projects be evaluated by all judges. The judges rated a total of 64 POM-84 project submissions on the six criteria developed previously. However, all judges did not rate all projects.

Next, a computer algorithm developed by Ford (1957) for determining overall rankings for incomplete judgments was applied to the rankings provided by the 13 judges to obtain an overall evaluation (rating or ranking) of POM-84 projects. The Ford algorithm has been used by Pelz and Andrews (1966) in evaluating the performance of research scientists, Arima and Mister (1972) in rating the effectiveness of R&D laboratories, and Doherty and Sorenson (1977) in evaluating research reports. The Ford algorithm yields a composite rating for objects by an iterative process that calculates the maximum likelihood estimates (W's) for each object, such that the probability of the ith object being judged higher than the jth object is:

$$P_{i>j} = \frac{W_i}{W_i + W_j}$$

With these calculated probabilities, the a priori probability of obtaining the matrix of results actually obtained may be determined. The ratings are then assigned for each object ranked that maximize this probability.

The Ford procedure was especially useful for this prioritization task because it (1) allowed each judge to rate only those projects with which he was most familiar, (2) placed no restriction on the type of scale used to make judgments, the type of scale anchors, the number of projects to be rated, or the number of judges required, (3) provided overall ratings or rankings for the projects, even though they were not all ranked by all judges, (4) did not require a group consensus, since ratings are combined quantitatively, and (5) avoided strong data assumptions required for other analysis procedures.

The Ford algorithm yielded composite ratings for each criterion for each of the 64 projects. These ratings were then converted to conform to the 1-10 scale requested by OP-01 (the result approximated sten scores, a normal distribution with 10 standardized categories using a 1-10 scale (mean = 5.5; SD = 2.0).[1]) This transformed the output from

[1]Note: Sten scores reflect large groupings of judgments. Sten scores of 4, 5, 6, and 7 reflect raw scores that are included between one SD below and above the mean--68 percent of the projects fall in this range. Scores of 1, 2, 3, or of 8, 9, 10 are out of the average range and may be considered as extremely low and extremely high values respectively.

the Ford analyses to the 1 (low) to 10 (high) point scale. The resulting scores were then used as NAVPERSRANDCEN's input to the POM-84 project submissions.

To determine whether the six criteria were, in fact, independent, measuring separate evaluation dimensions, or whether a smaller number of criteria could reflect overall prioritization, correlations were computed among criteria using output from the Ford algorithm. Next, a principal components factor analysis with varimax rotation (Nie, Hull, Jenkins, Steinbrener, & Bent, 1975) was applied to the correlations in an attempt to reduce the number of independent criteria. Table 1, which presents the correlations among the six criteria, shows that three, "payoff," "timeliness," and "importance," are highly correlated with each other; that is, a project that was rated highly on "payoff" was also rated highly on "timeliness" and "importance." These three criteria may represent one basic concept or superdimension of "importance." Although moderate relationships exist among "success," "importance," and "payoff," these three criteria do not represent a single concept. "Link to other work" and "validity" are mildly related to each other. Table 2, which provides results of the factor analysis, shows that two factors emerged. Factor I is represented by "importance," "payoff," and "timeliness," while Factor II is represented by "validity as an R&D project."

Table 1

Correlations Among Criteria for POM-84
Project Submissions Analysis

Criterion	1	2	3	4	5	6
1. Importance	1.000	.753	.778	.526	.373	.156
2. Payoff		1.000	.748	.453	.242	.350
3. Timeliness			1.000	.190	.060	.170
4. Success				1.000	.128	.024
5. Validity					1.000	.318
6. Link to other work						1.000

Table 2

Results of Factor Analysis of Criteria for
POM-84 Submissions Analysis

Factor	Component	Loading
I	Importance	.880
	Payoff	.857
	Timeliness	.831
	Success	.419
	Validity	.063
	Link to other work	.170
II	Importance	.316
	Payoff	.247
	Timeliness	.018
	Success	.138
	Validity	.878
	Link to other work	.334

Finally, overall ratings were computed by weighting each project's rating by the factor loading for the three important dimensions comprising Factor I. This was the most important factor, because it accounted for 49 percent of the total variance. These overall ratings were then transformed to the scale of 1-10.

The application of the Ford algorithm appeared to be a useful tool in the prioritization task. To determine its validity, it was applied to a listing of R&D requirements. Results are described in the following section.

R&D Requirements Prioritization Procedure

Existing and planned projects are directly related to the R&D requirements in MPT&HFE. However, for an integrated approach in conducting R&D, it is important that independent R&D requirements are determined. These requirements may then be matched to projects, particularly planned projects, so that discrepancies between requirements and projects can be identified and planning improved. Toward this end, NAVPERSRANDCEN generated a long list of people-related R&D requirements from Navy and DoD official sources (e.g., CNO Objectives, Scientific and Technical Objectives, SECNAV's Annual Civilian Management Guidance, etc.), which was subsequently reviewed, consolidated, and refined by senior NAVPERSRANDCEN researchers. The final list of 46 R&D requirements is presented in Appendix A.

Twenty-eight senior NAVPERSRANDCEN researchers (GM-13 and above) were asked to rate the 46 requirements. This group was asked to do the rating task so that their judgments could be incorporated into the basic planning process. While individual researchers cannot be technical experts in all areas represented by the list of requirements, they have sufficient expertise to evaluate a number of requirements on several important criteria. These criteria were the same as those used previously, except that "implementation" (the difficulty of implementing results) was substituted for "link to other work," because it seemed to be more relevant to a prioritization scheme.

As with the POM-84 rating task, correlations were computed using output obtained by the Ford algorithm, and the results were subsequently factor analyzed. Table 3, which presents the correlations, shows that three criteria--"importance," "payoff," and "timeliness,"--are highly correlated. No other pattern of correlations emerges. Also, as shown in Table 4, the clustering of these three criteria is supported by the factor analysis, since they comprise Factor I, which may be labelled as an "importance" factor. Factor II, which is represented by "implementation" and "success" and is considerably weaker, is related to the application of the R&D. Together, these two factors account for 67 percent of the total variance.

Table 3

Correlations Among Criteria for R&D Requirements Analysis

Criterion	1	2	3	4	5	6
1. Importance	1.000	.637	.851	-.170	-.088	.178
2. Payoff		1.000	.719	-.167	-.092	.052
3. Timeliness			1.000	-.139	.027	.200
4. Implementation				1.000	.350	-.229
5. Success					1.000	-.126
6. Validity						1.000

Table 4

Results of Factor Analysis of Criteria for R&D Requirements Analysis

Factor	Component	Loading
I	Importance	.853
	Payoff	.710
	Timeliness	.999
	Implementation	-.097
	Success	.018
	Validity	.140
II	Importance	-.162
	Payoff	-.135
	Timeliness	-.048
	Implementation	.668
	Success	.531
	Validity	-.281

It is important to note that Factor I for the 46 requirements corresponds directly to Factor I for the POM-84 project submissions, thus lending validity to the prioritization procedure. This was surprising since (1) the objects being rated in the two tasks were entirely different, (2) the judges were not the same, and (3) one criterion was not common to both ratings.

Future Prioritization Considerations

The process of quantitatively prioritizing R&D projects and requirements was feasible and yielded useful and interpretable results. If this process is to be used in the future to prioritize projects, it appears that the number of criteria used could be reduced. "Importance" is probably the most meaningful dimension, with "application of R&D" constituting a weaker dimension. However, since the specific criteria used for evaluation will affect the resulting factors, one approach would be to include criteria developed from other legitimate sources concerned with allocating resources to R&D. For example, the Defense Science Board (1981), in its report on the technology base, proposed a set of criteria for determining whether or not a technology would make an order of magnitude difference in deployable operational capability. Dimensions for three criteria--impact of opportunity, technical risks, and system/operational concept risks and costs--were developed, along with a methodology for ranking the various technologies on these criteria. Two examples of the criteria dimensions that would be appropriate for people-related R&D are: (1) pervasiveness (contribution of a technology to a wide variety of systems or missions) and (2) duration of impact (length of time a new technology remains superior).

Another approach would be to identify criteria by examining NAVPERSRANDCEN's end products. In this regard, it should be noted that Doherty and Sorenson (1977), in using the Ford algorithm in rating technical reports on 10 criteria, found two strong factors, which were represented by (1) applications to the Navy and (2) contributions to science. This finding is interesting, in that it corresponds with the recommendation made by W. Carey, former Associate Director of the Bureau of the Budget. He noted that research projects should be evaluated against two criteria: (1) potential benefits to society (e.g., the Navy) and (2) contribution to the scientific knowledge base. If these two criteria are included in the prioritization process, it appears that projects should be evaluated first on their value to the Navy and second on their scientific merits. Criteria used to capture these concepts could be subjected to empirical testing as described herein.

For future prioritization projects, it is recommended that:

1. Priority ratings made by NAVPERSRANDCEN R&D managers be compared with ratings made by other R&D managers.

2. Results obtained from using the Ford algorithm be compared with results obtained through other judgment procedures to determine their relative advantages and disadvantages.

3. A small set of relevant criteria for evaluating people-related projects and requirements be identified based upon results of empirical testing.

4. A procedure for weighting agreed-upon criteria and integrating them into an overall prioritization plan for decision making be developed.

5. Other criteria *from other valid sources* (e.g., the Defense Science Board) be included to ensure that the final set of criteria are most applicable to R&D projects prioritization.

R&D PROGRAM FRAGMENTATION

Background

There are several reasons for the fragmentation in R&D programs. Many offices are involved in the higher echelon management, sponsorship, claimancy, and review of research, development, test, and evaluation (RDT&E). These include (1) the Military Assistant for Personnel and Technology in the Office of the Under Secretary of Defense for Research and Engineering, (2) the Deputy Assistant Secretary in the Office of the Assistant Secretary of the Navy for Research, Engineering and Systems (ASN(R,E&S)), and (3) during the Carter administration, the Principal Deputy Assistant Secretary of the Navy for Manpower and Reserve Affairs (ASN(M&RA)).

Also, several principal advisors to the ASN(R,E&S) are designated to supervise R&D policy. These include the following:

1. The Director of RDT&E (OP-098), Office of the Chief of Naval Operations (CNO), is responsible to both CNO and ASN (R,E&S) for executing the Secretary of the Navy's (SECNAV) general responsibilities for planning, programming, and budgeting all RDT&E, with specific responsibility for the advanced development (6.3) and engineering development (6.4) categories.

2. For the Marine Corps, the Deputy Chief of Staff (RD&S) plans and executes the Marine Corps program for ASN(R,E&S).

3. The Chief of Naval Research (CNR) is responsible to SECNAV through ASN(R,E&S), for coordinating the basic research (6.1) category programs and for funding 6.1 research.

4. Currently, the Office of Naval Technology, under the Naval Material Command, is responsible for planning, coordinating, and directing the Navy's exploratory development (6.2) program. In the past, this was the responsibility of the Deputy Chief of Naval Material (Acquisition) acting as Chief of Naval Development (CND).

5. The Director of Navy Laboratories (DNL), who reports to the Chief of Naval Material (CNM) and to ASN(R,E&S), is responsible for the corporate management of all Navy laboratories.

This complex and changing management system is cumbersome and contributes to the fragmentation of people-related RDT&E programs.

In addition to the formal supervisory structures, various proposals affect R&D planning and management and contribute to fragmentation. For example, a September

1978 memorandum from the Under Secretary of the Navy[2] proposed that a high-level review board, co-chaired by ASN(MRA&L) and ASN(RE&S), with the Deputy CNO (MPT) (OP-01) as an executive agent, be established. The review board was to assess ongoing and proposed R&D projects, modify the nature and level of ongoing or proposed projects, and define and initiate new ones. OP-01 did make extensive arrangements to establish a review board and to provide staffing for it; however, the board is no longer active.

Other participants who increase the complexity of the R&D system and interact with the formal structures cited above include sponsors, claimants, users, and researchers. All of these participants design, propose, review, approve, or execute RDT&E based on their individual policy interpretation. As a result of the formal and informal involvement of many individuals at many levels, there are numerous directives to manage R&D and to make budget cuts, deferrals, and modifications. All of this results in further program uncertainty and fragmentation.

One difficulty with any attempt to reduce fragmentation has to do with the fact that the RDT&E laboratories have a limited supply of manpower and talent available. When there are insufficient researchers to both perform or manage high priority R&D projects, such projects must either be reduced in scope or not initiated at all. Related to this problem is the fact that research efforts involving macroproblems, such as attrition or retention, have been organized around one profession or discipline (e.g., personnel research psychologist) rather than a team representing several professions or disciplines (e.g., operations research analysts, economists, statisticians, organizational psychologists, etc.). When a narrow approach is taken to a macroproblem, comprehensive policy questions, such as "what level of attrition is acceptable to the Navy?" and "how can that level be achieved?," are not answered comprehensively. While individual research projects may be related to the area of concern, it is obvious that these research efforts do not constitute an integrated approach to the problem and would not have a major impact on the issues in question.

Initatives for Reducing R&D Fragmentation

The initiatives for reducing R&D fragmentation that have been undertaken or proposed by NAVPERSRANDCEN and other organizations are described in the following paragraphs.

Inclusion of NAVPERSRANDCEN in the CNM Laboratory Sytem

In 1975, NAVPERSRANDCEN was transferred from the Bureau of Naval Personnel to the Naval Material Command. One of the objectives was to increase the people-related R&D associated with the design of hardware and new platforms, and to increase human factors considerations in systems design and acquisition. This change has allowed NAVPERSRANDCEN to broaden its approach to problems.

[2]Under Secretary of the Navy (R. James Woolsey) Memorandum to VCNO, CNR, and CND; subj: Navy Manpower, Personnel, and Training Research, Development and Studies Program (MPT-RD&S), September 1978. The Principal Deputy ASN (M&RA) during the Carter administration originally proposed that this memorandum be issued as a SECNAV instruction. When the proposed instruction was not approved, the less formal memorandum (known as the Woolsey memorandum to organizations working in people-related R&D) was issued.

Establishment of a Planning and Appraisal Office

In 1980, NAVPERSRANDCEN established the Planning and Appraisal Office devoted to planning, programming, and appraising research work and evaluating the utilization of R&D end products. The functions of this office, which provides a focal point for integrating center-wide R&D planning, are to plan an integrated approach for identifying and prioritizing requirements, match existing and future projects to requirements, prioritize projects, appraise projects on cost versus payoff, and follow-up on effective use of end products. These functions are carried out in conjunction with the research groups and coordinated with their ongoing efforts.

Revision of NAVPERSRANDCEN Mission and Product Lines

In 1982, NAVPERSRANDCEN proposed that its mission be revised to reflect evolutions in R&D program direction. Under the revised mission, NAVPERSRANDCEN is to act as principal Navy RDT&E Center for manpower, personnel, education, training, and human factors and for providing technical support to the CNO in these areas. Also, NAVPERSRANDCEN is to be responsible for Navy-wide RDT&E leadership in the product areas of manpower management, personnel administration, organization management, education and training, and human performance. This proposed revised mission statement explicated NAVPERSRANDCEN's role as a focal point on all human resources R&D and clarifies its functions with respect to other organizations performing people-related R&D. Also, as shown in Table 5, Center product lines were redefined to correspond to the five product lines listed above, thus reducing the number of R&D categories and reorganizing some of the program areas. This organization of R&D characterizes Center programs more realistically and provides a framework for how they are represented in other reporting and documenting situations.

Development of R&D Plans for Addressing Large-scale Issues

Currently, NAVPERSRANDCEN is organized around the following seven research areas, which have been developed to address basic problems in manpower, personnel, and training R&D:

1. Management systems.
2. Personnel and occupational measurement.
3. Instructional technology.
4. Training systems.
5. Career development and retention.
6. Motivation and productivity.
7. Command and support systems.

However, there has been increased awareness of the necessity of organizing R&D programs around larger, more complex issues, requiring a multidisciplinary approach. As the complexity and size of the issues increase, the need to conduct projects employing a variety of research disciplines increases. Toward that end, areas for which R&D plans should be developed were identified by (1) mapping prioritized R&D requirements to existing R&D projects to identify high-priority requirements that were not being addressed, and (2) clustering these requirements within each of the product subareas. Through this process, it was determined that R&D plans should be developed for personnel retention, readiness and resource allocation, productivity, basic skills, on-site training, and human performance in command and control (C^2). R&D plans for two of these areas--retention of Navy personnel and human performance in C^2--are attached. Plans for the other areas are currently in draft form.

Table 5

NAVPERSRANDCEN Product Areas and Lines

Product Area	Product Line
Manpower Management	Requirements forecasting Manpower system simulation Projecting personnel inventories Compensation and cost models Manpower policy analysis
Personnel Administration	Occupational structures Selection and classification Computer-based accessioning Personnel advancement Distribution and assignment Performance appraisal
Organization Management	Resource allocation and readiness Attitude assessment Retention management Productivity enhancement Organizational effectiveness
Education and Training	Instructional program development Instructional delivery system Computer-based instruction Team training Shipboard training Training systems evaluation
Human Performance	Job design and job performance aids Information processing and decision making Man-computer interface design Human factors engineering Artificial intelligence and robotics Performance Measurement

In the retention plan (Appendix B), attempts were made to reduce fragmentation by demonstrating the relationship between existing R&D projects and research actions required to improve personnel retention. Individual retention projects conducted or sponsored by different groups have been reorganized to provide focus to an R&D issue area. The plan for human performance in C^2 (Appendix C) is aimed at (1) increasing fundamental knowledge of human information-processing capabilities and limitations, (2) coordinating this program with agencies responsible for C^2 system development and operational commands that are ultimate beneficiaries of such systems, and (3) providing sponsors with necessary guidelines for man-computer interfaces and user-computer task allocations.

Recommendations of DNL Mission Review Panel

The DNL Mission Review Panel reviewed the missions, roles, and functions of the Navy laboratories and reported findings to DNL and the DNL Corporate Planning Group in August 1982. The panel reported that the technology base is not only inadequately funded but also that it is excessively managed, in terms of both numbers and layers. NAVPERSRANDCEN believes that the panel's recommendation for addressing this problem--to increase the priority of technology base work and its funding and to reduce the levels of management in 6.2 and 6.3A work--would help reduce the fragmentation problem. Other panel recommendations were that (1) CNM assign 25 to 30 percent of the 6.2 funds directly to the R&D centers, an action that would greatly improve the individual centers' ability to develop an effective investment strategy for their technology base programs, and (2) the centers be given authority to adjust limited amounts of funds between R&D projects within the same program element. This increased authority would be commensurate with the responsibility already entrusted in the commanding officers and technical directors of the R&D centers and would help reduce the layers of management involved in R&D.

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APPENDIX A

RESEARCH AND DEVELOPMENT REQUIREMENTS FOR NPRDC

RESEARCH AND DEVELOPMENT REQUIREMENTS FOR NPRDC

The purpose of this taxonomy is to present research problems within manpower, personnel, training, and human factors research and development (R&D) in a systematic and comprehensive manner. These research problems are listed in order of priority within five topic areas:

A. Manpower Management
B. Personnel Administration
C. Organization Management
D. Education and Training
E. Human Performance

These topic areas are arranged, in general, in categories identified as NPRDC product R&D areas. Presenting these research problems in such a manner will allow (1) interrelationships to be seen more clearly, (2) gaps, deficiencies, or areas of excessive emphasis to be identified, and (3) a more rational and defensible allocation of resources to be achieved.

NPRDC plans to revise and update the taxonomy on a periodic basis. Comments on and suggestions for revisions to the taxonomy are welcome and should be addressed to Richard C. Sorenson, Code 03, NPRDC.

Research problems are presented below in order of priority within the topic areas.

A. Manpower Management

A.1. Define the number, quality (physical and mental), and type of people required to fulfill Navy missions. Provide methods for forecasting demands for both military and civilian manpower that consider (a) Navy mission, (b) fleet size, mix, location, operating demand, and (c) policy changes.

A.2. Determine the number and characteristics of individuals who will be qualified in the 1980s and beyond to staff the enlisted and officer corps, regular and reserve. Develop techniques for projecting the numbers, quality, and characteristics of accessions under (a) existing conditions and entry standards, (b) alternative standards, policies (e.g., draft), and compensation levels, and (c) mobilization conditions.

A.3. Develop analytic techniques and comprehensive compensation planning models linking enlistment incentives, retention incentives, pay scales, and retirement policies. Determine potential revisions to the military compensation policy and pay tables to encourage adequate enlistment, retention, and advancement. Develop a military pay adjustment mechanism that accounts for "comparability" (with the civilan sector as a whole), "competiveness" (with particular skills), and "equity" (more closely reflects the contributions, sacrifices, and risks associated with elements of the enlisted force).

A.4. Determine current and future numbers, kinds, quality, and pay scales of technical specialists in the civilian work force who have skills relevant to naval technologies who would be available for lateral entry at higher age(s) than presently recruited. Develop techniques for forecasting accessions of these individuals based on alternative compensation levels, personnel policies, and economic conditions. Analyze the effects of using such resources in terms of readiness, attrition, health care impact, and costs, etc. Develop and test procedures, modeling techniques, and management policies to support lateral entry programs, including prior service personnel.

A.5. Develop systems for analyzing manpower requirements, personnel policies, and available manpower supply on a comprehensive, integrated basis. Develop techniques for analyzing the trade-offs between alternative classes and mixes of personnel (officer, enlisted, civilian, contract, etc.).

A.6. Develop analytic techniques to forecast the size and composition (ability level, length of service, pay grade, ethnic, and gender mixes) of the Navy under alternative personnel policies (e.g., greater utilization of women).

A.7. Develop improved workload projection methodologies to provide a basis for allocating scarce manpower resources to organizational elements.

B. Personnel Administration

B.1. Develop methods for determining task components of jobs and for measuring job performance. Determine significant dimensions of job performance and develop aptitude and ability tests to predict job performance. Measure the change in tasks performed over time, as the incumbent obtains experience and as the team composition is modified. Classify skills required for performance of specified tasks.

B.2 Develop techniques for performance evaluation systems for officers and senior enlisted personnel that enhance selection, assignment, and promotion processes. Evaluate systems in terms of retaining high quality personnel and improving individual effectiveness.

B.3. Identify criteria and evaluate the distribution and placement systems. Develop and evaluate components for an improved system. Provide specifications for a comprehensive reassignment system to satisfy criteria. Evaluate feasibility, cost, value, and risk of implementing new distribution programs and assignment policies (e.g., geographic stabilization program).

B.4. Develop cost-effective computer-based classification tests that transcend measurement of academic skills. Exploit the capability of computers in developing performance measures (response latency, error patterns, etc.) and process measures (information acquisition and processing, brainwaves, etc.) and for use in task/stimulus presentation (dynamic graphics, videodisc, etc.) and in item sequencing.

B.5. Develop computer-based systems to facilitate vocational guidance and initial assignment in order to optimize the person-job match for enlisted personnel. Provide for more effective use of tests for personnel selection and classification.

B.6. Prepare career development planning models supported by appropriate selection and classification systems for officer and enlisted personnel. Assess the cost-effectiveness of the Navy's job rotation policy, the "up or out" policy, and the practice of providing professional education. Determine the value of alternative development paths.

B.7. Provide new criteria and methods for clustering tasks and jobs into occupational categories and for enhancing interchangeability or substitution of personnel. Assess the suitability of the existing enlisted/officer occupational and career structures for current or future Navy requirements. If necessary, develop alternative occupational/career structures.

B.8. Develop and evaluate career-enhancing techniques, procedures, and policies for selecting and assigning personnel for special duty (e.g., recruiters, instructors, etc.).

B.9. Assess the legal and EEO implication of testing, selection, and classification policies to ensure that (a) equal opportunity is provided for job assignment, career enhancement, etc. and (b) all tests and procedures are job relevant.

C. Organization Management

C.1. Identify the causes, costs, and cures for nonoptimal retention rates for key subclasses of Navy personnel. Develop and evaluate policies and management practices designed to improve the retention of these subclasses.

C.2. Develop techniques for objectively measuring readiness of operational units where feasible and identify proxy measures where necessary. Provide methods for relating manning levels and training to individual, team, and unit readiness.

C.3. Test and evaluate management techniques to determine which have high probability of improving productivity in the federal work force (civilian and military).

C.4. Develop data bases and analytic techniques for monitoring and forecasting retention of key subclasses of Navy personnel (e.g., pilots, women, petty officers, third-term enlistees, etc.). Develop retention forecasts at key career decision points associated with alternative Navy policies and external factors (economic, demographic, etc.).

C.5. Develop methods to evaluate the manpower and readiness implications of major policy decisions, such as decrewing during overhaul, dockside work week, or changes in the maintenance concepts and procedures.

C.6. Define organizational structures and management systems that effectively assimilate new personnel, particularly minorities and women, into working groups and commands. Determine changes, if any, required to adapt to an increased number of Hispanics in the force. Determine the impact on Navy operations of major adjustments in the male/female force ratio.

C.7. Identify, test, and evaluate methods to enhance leadership skills and increase technical supervisory effectiveness of chief petty officers.

C.8. Develop activity-level civilian workforce management techniques that integrate considerations of projected workload, personnel ceilings, or average strength, budget, promotion, and hiring constraints.

C.9. Determine characteristics of effective change facilitating policies, procedures, and agents. Develop methods to select and apply policies and procedures and to train change agents.

C.10. Develop and test organizational structures designed to improve effectiveness of shipboard and shore-based organizations.

D. Education and Training

D.1. Develop prototype programs that exploit hardware technology advances such as holography and microprocessors for expediting and enhancing training. Develop techniques for using artificial intelligence and cognitive science methodologies to improve instruction.

D.2. Determine the extent of skill deterioration that occurs after completing training (including training received by reservists on active duty), and develop a model to predict such deterioration as a function of the characteristics of the individual, the training, and the job. Identify categories of skills that must be practiced frequently to maintain proficiency. Develop improved training strategies that provide for increased retention of acquired technical skills or remediate technical knowledge and skill deficiencies to ensure maximum system operational readiness.

D.3. Develop techniques for selecting appropriate training methods and motivators for different instructional objectives and learner styles for classroom and job site training (e.g., to determine whether self-paced instruction, group-paced instruction, or a combination of both should be used to meet specific training requirements, or to what degree of training system fidelity is required for the application). Determine the validity of present or alternative procedures for developing the instructional objectives, content for training courses, and training evaluation procedures.

D.4. Develop techniques for diagnosing and correcting basic skill deficiencies during recruit, apprentice, and specialized skill training. Special consideration should be given to the needs of nonnative English speakers. Assess the cost effectiveness of training to a level of competence.

D.5. Identify and evaluate training techniques for effectively molding individuals and groups into smoothly working teams.

D.6. Develop tools and techniques for more effective training resource management, including techniques for training resources determination and allocation techniques, as well as for optimal schoolhouse scheduling.

D.7. Develop criteria for selecting the most appropriate time and place (e.g., schoolhouse, aboard ship, civilian institution, etc.) for specific categories and types of training.

D.8. Assess the adequacy of procedures for the planning and management of training both within Navy schoolhouses and aboard ship. Develop and test new management procedures, and methods for determining the cost effectiveness of training programs and for selecting among alternative training programs.

D.9. Determine how knowledge structures, cognitive processes, and basic information-processing capabilities required to perform complex tasks are acquired and how they influence learning and job performance. Develop instructional techniques that capitalize on individual differences to reduce training time without sacrificing the quality of training content.

D.10. Identify factors to increase the effectiveness of correspondence courses and other self-study programs. Develop innovative educational approaches to improve completion rates for self-study programs.

E. Human Performance

E.1. Develop improved methods for conducting hardware design and manpower requirements tradeoffs at early stages of the system acquisition cycle. Identify principles to be employed in systems and equipment design to reduce the quantity and quality of manpower required for operation and maintenance.

E.2. Identify methods to reduce the information load on the Commanding Officer and TAO of surface combatants during tactical engagements. Develop or identify existing decision aid packages as appropriate to enhance TAO performance under combat conditions. Improve systems to assist ship combat information center personnel in analyzing and employing tactical information arriving from nonorganic sensors and other widely-distributed sources.

E.3. Evaluate job performance aiding relative to technical training and assess trade-offs in terms of amelioration of critical shipboard performance problems. Provide design specifications for improved technical documentation for use in training and performance.

E.4. Develop simple, rapid, interactive interface between operators and equipment to improve performance and simplify operations (e.g., reduce excessive dependency on the human visual sense).

E.5. Develop procedures for determining manpower, personnel and training implications of advanced technologies. Determine methods to implement policy and procedural changes necessary to provide personnel to perform duties called for by such technologies.

E.6. Identify technological advances and improved policies and procedures to redesign operational jobs to enhance effectiveness and individual job and career satisfaction.

E.7. Develop and prioritize improvements in shipboard working/living environment; test high priority modifications.

E.8. Determine the factors influencing human information seeking and decision making and develop specifications for improved tactical and managerial systems.

APPENDIX B

A RESEARCH AND DEVELOPMENT PLAN FOR RETENTION OF NAVY PERSONNEL

CONTENTS

INTRODUCTION

Need/Requirement

With the advent of the All Volunteer Force in 1973, the Armed Forces have had to focus their attention and resources to attracting, retaining, and managing personnel. Retention of personnel is a continuing problem and the severity of this problem will likely increase in the 1980s as manpower requirements increase and the supply of military eligible persons decreases. The extent to which the Navy can maintain its force level and fulfill its mission is directly affected by its ability to use and manage its manpower resources and retain its qualified military personnel.

The importance of retention has been cited in several sources. For example, the Secretary of the Navy, in providing management guidance for the Navy (SECNAV memos, 11 September 1979 and 17 June 1980) indicated that:

> Retention of well trained military personnel of high quality is a top priority of the Department. We lose too many of these people just when they become most productive ... Even modest gains in retention will pay large dividends for the Navy and Marine Corps. The career enlisted force, especially those individuals highly trained in demanding technical fields, is of particular importance.

In a memo of 15 October 1979, the Chief of Naval Operations (CNO) amplified upon SECNAV's statements on retention by noting:

> Improved use of our resources through better recruiting and increased retention remains my priority objective and is the cornerstone of the Secretary's Guidance. In the long-term, the Navy's overall performance is tied to our ability to adequately attract, motivate, and retain qualified people at all levels. Every senior Navy civilian and military leader must actively pursue this goal. Innovative thinking and concepts, fresh analysis and unstinting individual leadership are key elements in achieving the objective of better resource management.

Further, in a memorandum of 11 December 1979, CNO noted that it was necessary "to continue pressure toward resolution of the retention problem . . . manning up the Navy must remain our highest order of priority . . . keep the entire chain-of-command focused on the retention problem."

At present, recent improvements in compensations/benefits coupled with economic uncertainties have improved the Navy's retention profile. It is unrealistic, however, to expect these economic conditions to continue throughout the decade. It is also unreasonable to expect Congress to continue to support large increases in compensation/benefits, given the present emphasis on weapon procurement.

To ameliorate the retention problem, a coordinated and integrated approach toward personnel management must be developed. In a recent GAO report on military attrition,[1]

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[1]General Accounting Office, Comptroller General of the United States; subj: Report to the Congress, Attrition in the Military--An Issue Needing Management Attention, 20 February 1980.

the Comptroller General noted that personnel management was hindered by the lack of management tools to evaluate the effectiveness of personnel policy decisions:

> Through its personnel management policies and practices, the military plays a major role in determining how well the sometimes opposing goals and characteristics of the individual mesh with the mission and requirements of the military. The military's most important charge is to seek that balance in management where individuals are motivated to remain and succeed in the service without completely eliminating the traditional military instructional environment. In so doing, the military can do more to reduce attrition without adversely affecting readiness. We found, however, that, because of the decentralization of authority and the weaknesses in policy and program evaluation systems, the services are unable to determine the most cost-effective approaches to long-term attrition management.

GAO recommended that the services "establish a more systematic approach to the development and evaluation of manpower and personnel policy and programs." Specifically, GAO recommended that the military's management information systems (MISs) be improved. Since current MISs do not track individuals throughout their enlisted careers, manpower planners are not able to study the dynamics of the personnel system. Therefore, quantitative techniques must be developed that model the personnel system and consider its complex dynamic nature. Such tools would enable manpower policy planners to determine how the enlisted force would respond to a proposed new policy. Before such tools can be developed, however, a comprehensive study of retention in the enlisted force is needed. Under this study, longitudinal data bases would be developed and analyzed to estimate system parameters.

Objective

The principal objective of this effort is to enhance the ability of the Navy and Marine Corps to manage enlisted/officer attrition and retention in a timely, cost-efficient manner. Specific objectives are to:

1. Enhance the Navy's ability to identify, forecast, and monitor retention problem areas.

2. Evaluate existing plans/policies and develop plans and policies to remedy major retention problem areas.

3. Test and evaluate the effectiveness of recommended changes, in terms of attrition/retention and associated costs.

RESEARCH PLAN

Identification of Subpopulations

Since overall retention rates are averages, they may mask particular subpopulations with the most critical retention rates. Thus, at the outset of this study, specific groups of personnel or subpopulations with retention rates that are most discrepant from the required rate will be identified and analyzed to determine how the identified groups relate to each other.

Critical Points Along Career Path

The rates and factors associated with retention will be identified at each critical point in the career path where significant losses occur. For enlisted personnel, the critical points are during recruit training, "A" school or apprenticeship training, initial duty station, completion of enlistment term, etc. For officers, the critical points occur at the end of initial commitment, when they come up for selection for Lieutenant Commander, etc. Since personnel attrite, reenlist, or decide to extend for quite different reasons at these critical points, the policy changes and interventions in career management that could improve retention at these points may also be different. Moreover, since the factors associated with retention may interact and vary over time, the relationships among these factors must be determined so that models, interventions, and systems designed for specific career decision points can be linked with those designed for the overall career path.

Action Steps

As shown in Figure B-1, the retention R&D plan will include the following steps:

1. Description and analysis of current retention levels.

2. Determination of the relationship among retention-related variables for subpopulations and at key career points.

3. Forecasts of future retention.

4. Determination of required retention rates.

5. Diagnosis and prioritization of present and future retention problems.

6. Assess existing policies and design new interventions/policies.

7. Test and evaluation of interventions/policies.

8. Comprehensive analysis and recommendations.

These steps can be associated with the various funding categories. As shown in Figure B-1, steps 1 and 2 would be basic research (6.1) or exploratory development (6.2); steps 3 through 5, exploratory development (6.2); step 6, advanced development (6.3); and step 7, engineering development (6.4).

The various research steps are described in the following paragraphs:

1. Description and analysis of current retention levels. Before current retention levels can be assessed, it is necessary to establish acceptable definitions of retention terms (e.g., retention rate, reenlistment rate, "careerist," attrition rate, etc.). This will allow research findings to be coordinated and key personnel subgroups to be compared systematically. Consistent methods for quantifying these terms also must be established.

The magnitude of current retention levels will be defined and historical data analyzed to determine retention patterns that may be compared with present retention data. In order to identify current retention levels, a state-of-the-art automated MIS will be developed and used to provide up-to-date retention statistics. This system will not only enhance the operational and research communities' ability to discover potential

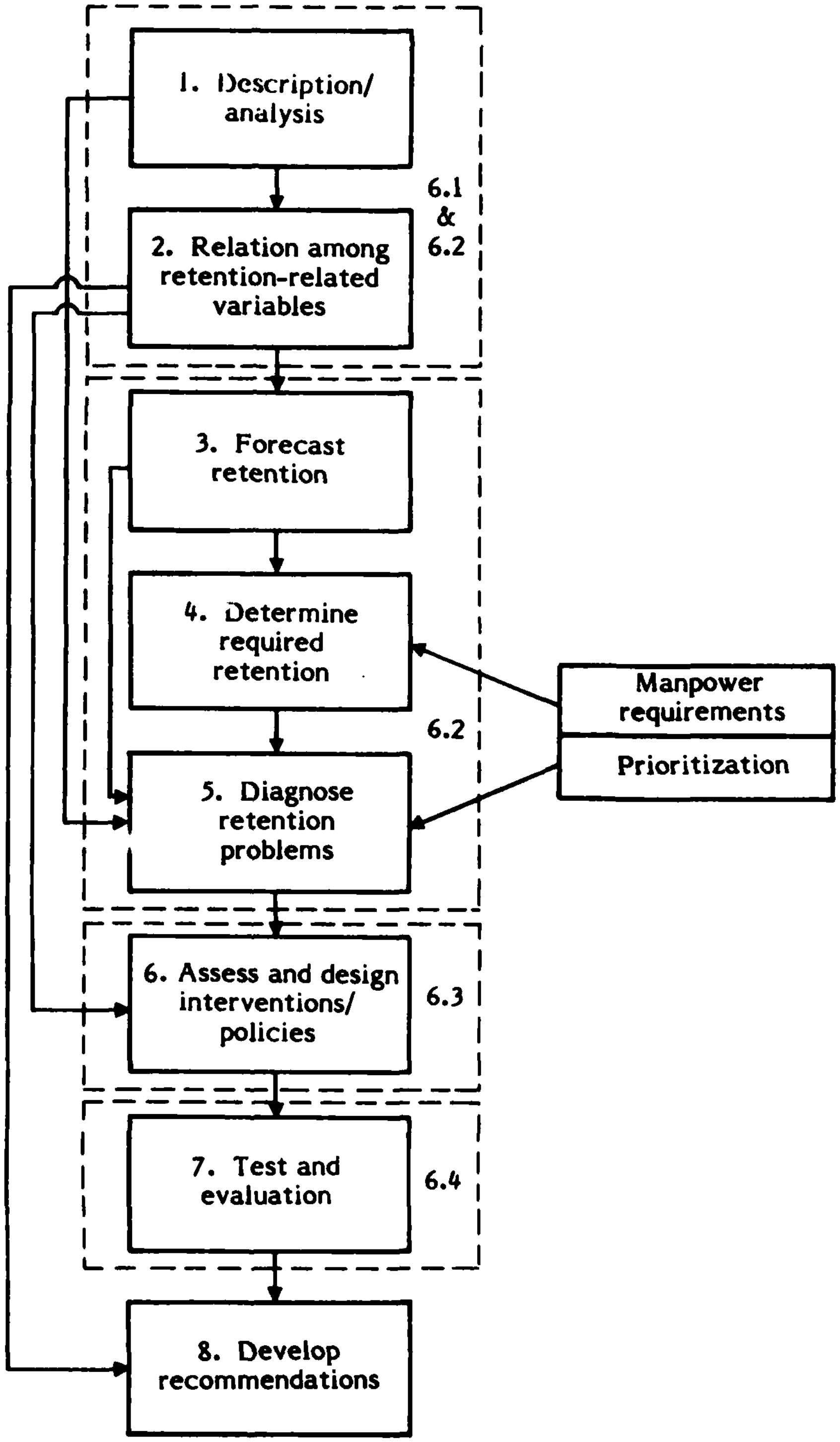

Figure B-1. Action steps for retention plan.

problems in a timely, cost-efficient manner, but will also provide retention information for use in determining how policy changes affect retention.

2. Determination of the relationship among retention-related variables for subpopulations and at key career points. Since retention-related variables interact with the subpopulations and career points being studied, these variables will be considered in a multivariate design as part of a complex interactive system in which combinations of retention factors are investigated. By integrating data bases and analyzing available data, factors related to retention can be identified for subpopulations at different points in their career. These include (a) factors related to the individual (demographics, skills, interests, ability, attitudes, etc.), (b) factors related to the organization (crisis management, reduced manning, etc.), (c) factors specific to occupational factors of various subpopulations, (d) factors related to organizational policies (Department of Defense and Navy directives), and (e) factors that are external to the Navy (economic conditions, societal attitudes, etc.).

3. Forecasting of future retention levels. Quantitative techniques will be developed to forecast future retention levels. By integrating the identified retention-related variables (2 above) with information regarding their saliency in the future (e.g., airline forecasts for hiring Navy pilots), future retention levels may be predicted and used to aid in identifying retention problems in the 1980s and beyond.

4. Determination of required retention rates. To determine the most desirable present and future retention levels, manpower requirements must be accurately specified and prioritized in terms of functions and mission requirements. This will be done by using comprehensive requirements models, in which requirements will be viewed as external input to the analysis of retention levels. Issues to be addressed in the delineation of requirements and their corresponding priorities include the mix of personnel (including skills, ratings, length of service), personnel quality (e.g., mental category and H.S. diploma), etc.

5. Diagnosis and prioritization of present and future retention problems. By analyzing the discrepancies between the current and required retention levels for both overall personnel and specific subgroups, retention problem areas may be identified. Retention problems will then be prioritized, taking into account such factors as the magnitude of the numerical deficiencies between current and required retention levels, the criticality of specific subgroups, the cost and duration of training, the personnel supply available external to the Navy, the probability of solution, estimated cost-benefits, etc. In addition, the predicted future retention levels determined in step 3 will be matched with future requirements determined in step 4 to identify and prioritize future retention problems.

6. Assessment of existing policies and design of new interventions/policies. By analyzing the relationship between (a) retention-related variables and (b) projections of desired and probable retention rates, determine the extent to which current policies contribute to or alleviate retention problems. Based upon this assessment and the problem priorities, where warranted, intervention strategies and policies will be formulated that have potential for ameliorating the retention problems. These interventions and policies will be developed by such methods as (a) simulation studies (e.g., to determine how a change in compensation would affect retention), (b) surveys (e.g., to determine how personnel would perceive a policy change), and (c) experimental changes (e.g., in organizational structure, job redesign, remedial training, etc.). These methods would provide preliminary tests, analyses, and evaluations. Outcomes produced would include a set of major recommendations for interventions and policies to be tested on a

broad scale. This phase will also include the development of the methodology required for a particular intervention, the technology to be applied to Navy problems, and the accompanying evaluation plan and cost-benefit analysis.

7. Test and evaluation of interventions/policies. These tests, which follow directly from the design phase (step 6 above), would include large-scale field experiments, evaluations of major policy changes, and evaluations of large systems (e.g., officer distribution system). These interactions will (a) require the participation of several commands, (b) include short- and long-term evaluations, as well as cost benefit analyses, (c) lead directly to specific and broad-based policy recommendations, and (d) be evaluated in terms of both retention and important outcomes (e.g., performance, morale, unit readiness, etc.). Certain retention interventions may in fact encourage the least productive individuals to remain in the military for a time, only postponing losses and presenting other problems for the Navy.

8. Comprehensive analyses and recommendations. Recommendations will be based on outcomes from the tests and evaluations (step 7 above), results from previous research on retention, and cost-benefit analysis.

RESEARCH STRATEGY

First Priority Projects

To identify and ameliorate retention problems systematically, the following projects will be given first priority.

1. Development of enlisted and officer data retrieval systems. Existing retention-related data bases will be integrated, wherever possible, to create the NPRDC Retention Data-Base System. Some of the data bases to be included are data from the voluntary out (VOLOUT) and selected retention studies, the enlisted and officer exit questionnaires, the enlisted and officer survival tracking file, and the Navy Health Research Center's cohort file. This computerized system, which will be capable of monitoring present and retrieving past retention/continuance rates, will be user-oriented through the design and installation of interactive modules. Additionally, it will serve as a rich research data base by providing information for user-defined cohorts.

2. Development of the NPRDC "cohort" survey information system. Each year, sample cohorts to be studied will be identified. These cohorts will be surveyed periodically to obtain longitudinal information, attitudinal data, etc. Questionnaires administered will be developed by a team of researchers, with divergent backgrounds and interests.

3. Determination of "optimal" retention rates. Analytical techniques and systems will be used to transform requirements for specific subgroups into desired retention rates for these groups. Wherever necessary, techniques will be developed to determine the appropriate retention levels consistent with mission functions.

4. Development of a "problems" priority system. As part of the research design, retention problems will be identified for a specific subgroup at a particular point in the career cycle. These problems will then be prioritized, based on criticality, cost of personnel replacement, impact on readiness, difficulty of solution, etc. A single composite criterion will be used to determine the order in which problems should be addressed.

5. Development of intervention strategies and models to enhance retention. Results from subprojects 1 through 4 above will be integrated to formulate interventions and recommendations designed to enhance retention. Past and present retention research has focused on general detail (GENDET) personnel, women, surface warfare junior officers, pilots, etc. Those populations not already being addressed in ongoing research will serve as the primary targets for future research.

End Products

The principal end products will be a comprehensive set of policy and individual command interventions, models, systems, and data bases designed to (1) monitor retention, (2) recognize and forecast potential retention problems, (3) test and evaluate proposed changes, (4) determine positive and negative effects of proposed interventions on other outcomes (e.g., productivity), and (5) enhance the Navy's ability to anticipate and react to previously identified problems. As these end products are developed for various career stages and subpopulations, the methodologies used, analyses conducted, results obtained, and policy recommendations made will be described in a series of technical reports, interim reports, and working papers. Information from all these media will be integrated to formulate comprehensive interventions, methodologies, and systems as appropriate.

RELATED WORK

A number of NPRDC research studies have served as the basis for this plan. In general, these studies have focused on accessioning, classification, and first-term enlisted attrition and were not comprehensive enough to provide overall solutions. However, the results from past and present work will be incorporated into future plans.

Table B-1 lists recent and current projects in attrition/retention and indicates how they relate to steps in the R&D retention plan. This serves to identify research gaps and required steps needed to fill them, and illustrate linkages between the various programs.

Brief descriptions of the ongoing projects in attrition/retention are provided in the following paragraphs:

1. Personnel distribution and career development. This project was developed from results of a study of surface warfare junior officer (SWJO) retention, which showed that the assignment process was a critical contributor to their satisfaction/dissatisfaction with making the Navy a career. It will assess the present level of retention of SWJOs and determine factors in the career path and distribution systems that affect retention.

2. Methods for projecting petty officer retention. This project will use the HRM data base to identify organizational and attitudinal factors related to retention of petty officers. In addition, "Odds for Reenlistment" prediction equations will be developed, with emphasis on in-service variables and classifications, correlates of eligibility, and the concomitants of reenlistment rates.

3. Retention planning models. This project will develop a set of quantitative tools to enable planners to estimate retention levels. It will be built on a foundation of accession planning models, enlisted programming systems, and the cohort continuance models that provided information on the structure of a longitudinal data base and survival methodology.

Table B-1

Recent and Current NPRDC Attrition/Retention Projects

Project	Subpopulation	Career Point	Associated Step(s) in R&D Retention Plan
1. Personnel Distribution and Career Development	Officers	Career decision point	Description and analysis; diagnosis (Steps 1 & 5)
2. Methods for Projecting Petty Officer Retention	Selected Ratings	End of second and third enlistment	Description and analysis; determination of retention-related variables (Steps 1 & 2)
3. Retention Planning Models	Total Force	Career decision point	Description and analysis; retention-related variables; diagnosis; design policies (Steps 1, 2, 5, & 6)
4. Accession Planning	Enlisted	Prior to entry	Forecast; diagnosis; design policies (Steps 3, 5, & 6)
5. Officer Personnel Management Models	Officers	Career decision point	Diagnosis; design; policies (Steps 5 & 6)
6. Compensation and Incentives for Military Force Management	Enlisted	Career decision point	Test and evaluation; recommendations (Steps 7 & 8)
7. Retaining Qualified Enlisted Personnel	Enlisted	End of first-term enlistment	Determination of attrition-related variables (Step 2)
8. Identification of Mitigating Variables	Enlisted	End of first-term enlistment	Determination of attrition-related variables (Step 2)
9. USMC Exit Survey System	Enlisted	All loss points	Description and anlaysis; factors related to attrition (Steps 1 & 2)
10. Revised Recruiting Systems	GENDETS	End of first-term enlistment	Design of interventions (Step 6)
11. First-term Attrition--Women Marines	Enlisted Women Marines	End of first-term enlistment	Description and analysis; factors related to attrition (Steps 1 & 2)
12. Training Approaches to Counter Attrition	GENDETS	End of first-term enlistment	Design of interventions (Step 6)
13. Organizational Interventions to Reduce Attrition	Enlisted	End of first-term enlistment	Determination of attrition-related factors; design of interventions (Steps 2 & 6)
14. Evaluation of Retraining Approaches to Counter Attrition	Enlisted	End of first-term enlistment	Design of interventions (Step 6)
15. Retention of Career Personnel in Critical Ratings	Enlisted	All enlistment terms	Determination of retention-related variables; design of interventions (Steps 2 & 6)
16. Career Management Planning	Enlisted	All loss points	Description and analysis; diagnosis; design of interventions (Steps 1, 2, & 6)

4. Accession planning models. The objectives of this project are to (a) identify and measure those variables that determine the manpower supply in the 1980s and beyond and (b) develop policy-oriented planning models to match manpower requirements with the available manpower supply pool. Outcomes and methodologies will aid in determining the desired retention levels.

5. Officer personnel management models. The intent of this project is to develop a set of user-oriented, computer-based models and programs that will permit planners to develop an officer force to meet manpower requirements. These would include a mathematical model that determines (a) the appropriate number of accessions to select from each commissioning source, and (b) how these people should be distributed among communities to meet anticipated future requirements.

6. Compensation and incentives for military force management. The purpose of this project is to develop tools to allow Navy managers to determine how new or planned compensation policies will affect retention.

7. Retaining qualified enlisted personnel. The primary objective of this project has been to determine why first-term enlisted personnel attrite by longitudinally surveying a cohort of enlisted personnel and relating response data to performance and attrition variables. Results should help manpower planners determine why attrition is so high during first-term enlistment and identify specific problem areas in terms of critical attrition points.

8. Identification of mitigating variables in enlisted screening. The purpose of this effort is to develop an enlisted screening system, specifically a biodata questionnaire, that is effective in determining those applicants who are most likely to complete their initial tour of duty. This screen will be used to determine factors related to attrition. Applications might be important in incrementing the validity of existing operational screening devices, as well as improving the personnel classification system.

9. USMC exit survey system. This project is developing an information system on the reasons why personnel separate from the Marine Corps. Information obtained will be used by management in making decisions concerning policies and practices that impact on attrition. Similar systems were developed previously for Navy officer and enlisted personnel and are beneficial in determining why personnel do not reenlist.

10. Revised recruiting systems. This research is attempting to increase the numbers of enlisted personnel recruited into the Navy by two methods: (a) identifying promising marketing techniques and training recruiters to use them, and (b) identifying an increased target population. These methods will be pilot tested in an experimental setting, and results used to develop recommendations for improving recruitment.

11. Assessment of first-term attrition of women Marines. This project will identify the factors affecting attrition of women Marines during their first enlistment and provide recommendations to address significant problem areas.

12. Training approaches to counter attrition. This research is attempting to reduce the attrition and disciplinary actions of the GENDET force by developing, testing, and evaluating an integrated system of interventions designed to facilitate adjustment to military life and shipboard duty. Results will be used to develop policies for changing some existing training procedures.

13. Organizational interventions to reduce attrition. The objectives of this effort are to (a) identify managerial factors related to disciplinary actions and first-term attrition, and (b) develop and test ameliorative managerial actions to reduce attrition. In one pilot test, two films, which were designed to provide newly arriving recruits with more realistic perceptions of basic training, were evaluated. The results of this project will provide decision makers with policy recommendations on reducing attrition for first-term enlisted Marines.

14. Evaluation of retraining approaches to counter attrition. This research examines the effectiveness of two pilot correctional custody units designed to combat disciplinary problems, poor performance, and attrition in first-term enlisted personnel. Program effectiveness is being evaluated by comparing subjects to a control group consisting of individuals with similar disciplinary records who were not assigned to correctional custody in terms of job performance, disciplinary records, and survivability in the Navy.

15. Retention of career personnel in critical ratings. This effort investigates reenlistment incentive packages to be offered at the first, second, and third reenlistment points. Survey techniques will be used to determine the incentive levels needed to achieve desired retention. Cost/benefit analyses will be performed on the various incentive alternatives.

16. Career management planning. This effort will develop network models to design career paths that balance tradeoffs between retention, performance, and cost. The models will enable policy makers to assess the major impacts of assigning enlisted personnel to various career paths.

FUNDING REQUIREMENTS

Item	FY83	FY84	FY85	FY86	FY87
Professional Man-Years:					
Psychologists	16.0	19.0	26.0	26.0	26.0
Statisticians	4.0	6.0	7.0	7.0	7.0
Operations Research Analysts	5.0	6.0	7.0	7.0	7.0
Economists	8.0	11.0	12.0	12.0	12.0
Computer Pro grammers	2.0	3.0	3.0	3.0	3.0
Mathematicians	5.0	5.0	5.0	5.0	5.0
Total	40.0	50.0	60.0	60.0	60.0
Civilian Labor & Overhead ($K)	2453K	3066K	3679K	4292K	4905K
Military Man-Years	5.00	7.25	8.50	9.75	11.00
Military Overhead ($K)	193K	241K	289K	337K	385K
Contracts	1876K	2345K	2814K	3283K	3752K
Funding Categories:					
Basic Research (6.1)	271K/6%	339K/6%	271K/4%	237K/3%	
Exploratory Development (6.2)	1989K/44%	2373K/42%	2712K/40%	2769K/35%	2712K/30%
Advanced Development (6.3)	2034K/45%	2373K/42%	2780K/41%	3323K/42%	2712K/30%
Engineering Development (6.4)	226K/5%	565K/10%	1017K/15%	1582K/20%	3615K/40%
Total	4520K	5650K	6780K	7911K	9039K

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APPENDIX C

HUMAN PERFORMANCE IN COMMAND AND CONTROL (HPC^2) PROGRAM PLAN

INTRODUCTION AND OVERVIEW

The process of command and control (C^2) of forces is the most fundamental aspect of military operations. It is the key to the timely application of military force in response to threats. Although the process relies upon sensors, weapons, computers, communications, and available manpower, it depends primarily upon human cognition and decision-making activities. These activities reside in the commander of naval units and consist of the assessment of tactical situations, the formation of action alternatives, the selection of actions to meet a specified objective, the issuance of orders, and the control of their execution.

According to this view, equipment, software, and personnel resources are effective only if they are properly coordinated and directed in force deployment and combat. There is no question that hardware must be developed, software must be written, and personnel must be recruited, selected, and trained. These resources have military value only when they are integrated by the commander in performing his mission.

The Joint Chiefs of Staff Publication 1 defines C^2 as follows:

> Command and control is the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures, which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of his mission.

This formal definition recognizes the role of equipment and personnel resources, but these are seen as the means by which the activities of "planning, directing, coordinating, and controlling" are effected to determine operational readiness. This set of activities, then, is the hallmark of the C^2 process. Its core is command decision making--that complex cognitive function that includes information processing (the collection and transformation of raw data), inference (the diagnosis of an uncertain environment), action selection (the formation of action alternatives and choosing among alternative courses of action), and outcome evaluation (the monitoring of the system's effect on the environment).

Human performance is the essence of C^2. A C^2 system is of little value without its sensory links to the environment, but information must be processed--organized, transformed, correlated, and integrated--to yield meaningful ingredients for the ultimate functions of action selection and execution. These are all cognitive, intelligent processes that even the most advanced hardware and software system technologies alone cannot deliver.

People as information processors and decision makers have a vital role to play in C^2 systems. A program of people-related R&D directed toward these processes can best ensure that this role is an effective one. This program plan provides for a strong base of technology in human performance in C^2 and the active application of this technology to the Navy C^2 community.

PROBLEMS AND ISSUES

Human Information Processing and Decision Making

In recent years, there has been remarkable growth in the technical capabilities of C^2 systems. The range and accuracy of sensor and intelligence information have increased dramatically; weapons have grown in sophistication and range, permitting controlled deployment on a world-wide basis; and the swift transmission of large amounts of data from widely dispersed sources is now feasible through computer and satellite communication networks.

Unfortunately, the rapid advancements in these technologies have not been accompanied by a concomitant increase in operational effectiveness. The consensus of command and staff officers is that, despite the technical achievements in weapons, sensors, and computers, current C^2 systems remain inadequate. They fail to meet the anticipated needs of future combat, to support the capabilities of modern weapon systems, and to exploit fully the state-of-the-art technical base.

For instance, the World-Wide Military Command and Control System (WWMCCS), which serves as the primary C^2 system for the National Command Authority, is so cumbersome to use that only a portion of its capability is realized. The information that it contains is frequently inaccurate or incomplete and, in times of crisis, the system is intolerably slow. Theoretically, 96 percent of all information required for force management is available through WWMCCS; however, because of poor system design, commanders must make decisions without the benefit of the WWMCCS data base. Similar problems are apparent at the platform level. The Navy Tactical Data System (NTDS) is difficult to operate and maintain and has required extraordinary training efforts by fleet and type commanders. Further, software changes that might relieve the operation and maintenance problems are difficult to implement because of system complexity.

A major failure of these and other C^2 systems has been their inability to transform new hardware and software capabilities into the reality of increased operational effectiveness. Why is the promise of these technologies so often unfulfilled? There are no simple answers, but several indicators point to the critical role of human performance in C^2 operations.

The ability of humans to process and use information is rich and impressive but is, after all, finite. As hardware and software subsystem capabilities make excessive demands on human abilities, the promise of increased effectiveness is not attained. Overall system performance is not enhanced but, rather, is sometimes degraded. Subsystem capabilities that do not contribute to overall effectiveness are, in effect, squandered resources. An appeal may be made for increased manpower and skill levels, but these cannot redress the basic limitation.

Equipment and software developments are the driving force behind the acquisition of C^2 systems. The assumption is that, if larger memories, faster computers, more sophisticated algorithms and displays, etc., are available, they are desirable and necessarily productive. The notion is that somehow these technologies will be exploited by the users of the system.

The reality is otherwise. The commander and his subordinates are immersed instead in a system of increased complexity. Sophisticated subsystems do provide for data acquisition, transmission, computation, storage, and display, but the abilities of humans to utilize and manage these resources for information processing and decision making is limited. System designs that ignore these limitations are destined to contribute to the problem and not to its solution.

The key issue in this area is that insufficient recognition of human information-processing and decision-making capacities and limitations contribute to poor system design.

Man-computer Interface

In modern warfare, it is difficult to imagine a C^2 system that does not involve man-computer interactions. However, all is not well at this critical man-computer interface. Even when the human's role is well within his processing limitations, the required interactions with the information system are all too often awkward, inefficient, and counterproductive.

For example, the data retrieval procedures for the WWMCCS Query Module force the user to preprocess and translate desired queries into an artificial low-level language. The result is a stilted and formalized interaction that is achievable only by specially-trained operators. Wholesale nonuse of the system ensues, and the anticipated level of system performance is never realized.

Perhaps one should not be surprised if the 1960 visions of man-computer symbiosis have not been realized in the 1980s. Although system software, with its special promise of flexibility, was supposed to be the salvation, today's software is as rigid as yesterday's hardware. Computer programs for C^2, in whatever language they are written, are exceedingly complex constructions. Like hardware, they require long lead times for development and, again like hardware, they quickly become cast in concrete and resist efforts of redesign. Unfortunately, software specialists, like hardware engineers, are not sufficiently sensitive to the special needs of the system users.

The key issue in man-computer interface design is that the lack of sensitivity to users' special needs results in degraded system performance.

Human Performance Measurement

The measurement of C^2 system performance is essential. The evaluation of current operational readiness and thereby the requirements for future systems acquisition cannot be determined without such measurement. While equipment and software performance are important contributors to overall C^2 system evaluation, they are clearly less than the entire story. Human performance emerges as a key ingredient of the whole, especially in the cognitive realms of information processing and decision making.

Although the relatively straightforward performance measures for equipment and software (e.g., voltages in cabinets and computation speeds of computers) may seem to be representative descriptors of the system, they are at best only subsystem measures. The ease of quantification of such measures and the authority of the disciplines that promote them can lead to serious oversights. Truly inadequate systems may be declared satisfactory merely because hardware and software meet their specifications. Perhaps worse, the specifications are made more demanding, more costly engineering technology is introduced, and the new system still does not perform as desired.

It is much more likely that human performance, interacting as it does in unpredicted ways with equipment and software subsystems, is at the core of the problem. This is especially true if human capabilities and limitations have been ignored in the rush to produce an operational C^2 system. If more effective C^2 systems are to be developed, the problem of measuring human performance and assessing its impact in complex systems must be addressed.

<u>The key issue here is that the evaluation of C^2 systems requires valid measures of human performance.</u>

OBJECTIVES

Based on the above problem and key issues, a set of essential objectives can be derived. In achieving these objectives, it is important to avoid short-term, crisis-oriented remedies to isolated C^2 problems. Instead, an integrated R&D effort is required in which general design principles are identified and applied throughout the development of C^2 systems. Accordingly, the Human Performance in Command and Control (HPC^2) program emphasizes the need to assemble meaningful human performance guidelines for C^2 system design and provides for human performance expertise as required throughout the system life cycle. The objectives of this program are:

- To augment fundamental knowledge of human information-processing capabilities and limitations.
- To enhance the effectiveness of the man-computer interface in existing and future C^2 systems.
- To measure human performance and predict its impact on C^2 system effectiveness.
- To provide for the systematic application of human performance technology throughout the C^2 system life cycle.

APPROACH

General

The approach consists of (1) development of a research and development program that addresses the skills and limitations of the human information processor/decision maker, and (2) a close coupling of this program with agencies responsible for C^2 system development and those operational commands that are the ultimate beneficiaries of such systems. This approach responds to the acknowledged needs of C^2 program managers to improve the human performance aspects of C^2 systems design and operation.

The planned R&D program is interlocking. The information provided by each set of projects is input to both the system acquisition process and to subsequent HPC^2 R&D. The overall program execution is closed-looped. Consumers are an integral part of a feedback process that provides testbeds for research products and inputs for new product design and evaluation.

Steps already have been taken to form the basis for an integrated R&D program. Working relationships with several Navy commands and laboratories have established testbeds for people-related R&D in information processing and decision making. This family of testbeds includes C^2 systems at the naval air, surface, subsurface, fleet, and task force levels.

The air system testbed is provided by the Naval Weapons Center and the Naval Air Development Center. The surface testbed resides within the Fleet Combat Direction Systems Support Activity, which is responsible for maintaining software for NTDS. Subsurface testbeds have been identified within Commander, Submarine Force, U.S. Pacific Fleet and the Naval Submarine Training Center, Pacific. The Naval Ocean Systems Center has established a large-scale testbed for R&D on fleet and task force C^2 systems. This installation, the advanced C^2 architectural testbed, provides the opportunity to test and evaluate command and individual user performance with newly developed C^2 systems and technologies. NPRDC facilities contain the computers and equipment necessary to examine individuals and small groups in a controlled laboratory setting.

The remainder of this section describes the specific approaches, in terms of tasks, products, and consumers, for meeting each of the objectives identified in the previous section.

Objective: To augment fundamental knowledge of human information processing capabilities and limitations

This most fundamental objective of the HPC^2 plan requires the determination and description of relevant human information-processing parameters in the context of manned C^2 systems. This approach lays the groundwork for subsequent R&D relating to the man-computer interface and the measurement of human performance in complex systems. It emphasizes experimental investigations in which the operator/decision maker must attend to, process, interpret, and act on complex information inputs. The tasks, testbeds, products, and consumers of this approach are listed below.

1. Tasks:

a. Perception, memory, and attention. Investigate human limitations in perceptual processes, memory capabilities, and attentional mechanisms as these affect the decision maker's ability to seek and assimilate information quickly and accurately.

b. Degraded information. Study the effects of unreliable, incomplete, conflicting, and irrelevant information on decision-making performance. Develop guidelines for possible application to the design of threat-evaluation subsystems.

c. Decision heuristics. Explore heuristic devices that humans use as coping mechanisms to simplify complex decision problems; investigate techniques to exploit their strengths or correct their weaknesses as appropriate.

d. Stress. Conduct experimental studies on the effects of stress induced by noise and sleep deprivation on simple and complex decision making (in cooperation with the Naval Health Research Center (NHRC)).

2. Testbeds--NPRDC and NHRC laboratory facilities.

3. Products--The expected products of the above tasks are data and models that contribute to a description of the individual performance envelope in information-processing and decision-making tasks. These include bounds and specifications of a decision-maker's performance when faced with dynamic, multiple-demand tasks of the kinds anticipated in C^2 combat systems. These products will be disseminated in technical reports, journal articles, briefings, presentations at professional meetings, and informal research communications as appropriate.

4. Consumers--The primary consumers of this information will be human factors engineers and researchers in the scientific community. These products also serve the internal development of the HPC^2 program as it pursues its more applied C^2 objectives.

Objective: To enhance the effectiveness of the man-computer interface in operational and future systems

Operational readiness of C^2 systems depends upon the critical man-computer interface where the capabilities of sensors, computer data analysis, and weapons control interact with the decision maker who is responsible for their employment. Careful design of this interface will ensure payoffs in increased combat effectiveness; poor design can degrade potential system capability. The HPC^2 program approaches the man-computer interface problem through experiments and analyses that address both operational and future systems. The components of these systems are presented below.

Operational C^2 Systems

1. Tasks:

a. Displays. Evaluate interactions of users with CRT information displays. Make recommendations as appropriate for altering format, content, and symbology as required by the user's mission and task requirements.

b. Data and action entry. Test interactive methods for data entry and user actions that affect weapons control, sensor control, and display alteration. Provide specific recommendations for the redesign of data and action entry panels and operational modes.

c. Console operation. Develop computer-based interactive training packages to assist operators in learning the details of console operation and to assist commanders in evaluating and configuring tactical C^2 information.

d. Retrofit of interactive software. Gather data to assist operational commands in specifying and justifying requests for software alteration that affect the man-computer interface.

2. Testbeds:

a. Surface Systems: Fleet Combat Direction System Support Activity, Pacific (NTDS)

b. Subsurface Systems: Commander Submarine Force, Pacific Fleet; Naval Submarine Training Center, Pacific.

c. NPRDC: System Simulation Facility.

Future Man-computer Interface Systems

To build more effective C^2 systems for the future, designers require empirical information about human performance with various hardware and software configurations. Therefore, the HPC^2 program will investigate the dynamics of the man-computer relationship and make design recommendations for prototype systems.

1. Tasks:

a. Query systems. Design, develop, and test interface techniques for querying large data base C^2 systems.

b. Decision aiding. Develop and evaluate decision aids. Ensure that they are operationally relevant and incorporate effective, efficient communication between the user and the computer.

c. Display controls. Investigate the suitability of proposed man-computer interfaces in the display functions for zoom, pan, and window controls. Submit integrated designs and verify as appropriate.

d. Graphics and color. Evaluate graphics and color technologies in prototype CRT displays.

e. Artificial intelligence. Investigate techniques at the man-computer interface that will exploit new software advances in artificial intelligence.

2. Testbeds.

a. Naval Ocean Systems Center: Advanced Command Control Architectural Testbed.

b. NPRDC: System Simulation Facility.

3. Products--Technical reports will describe the performance of the operator/decision maker in a variety of man-computer interface situations. They will contain recommendations for the use of designers and system architects. New query and action entry modules, candidate decision aid packages, and other software also will be produced. These will be available for testing within a total system context.

4. Consumers--The agencies responsible for planning and procuring C^2 systems must have detailed information on which to base the design of man-computer interfaces. NAVELEX, NAVSEA, and NAVAIR require operationally relevant, empirical data on which to base design criteria. The Defense Communications Agency and CNO (OP-94) will benefit by having people-related data on which to base decisions concerning large-scale system integration.

Objective: To measure human performance and to predict its impact on C^2 systems effectiveness

Although it is clear that man is a significant component in C^2 systems, the measurement of human performance is all too often neglected. Given man's inherent processing limitations and the substantial problems at the user-computer interface, it becomes imperative to measure human performance and to assess its impact on overall systems effectiveness. The approach of the HPC^2 program is to (1) develop improved methodologies for measurement, (2) quantify complex human individual and team performance in C^2 tasks, and (3) analyze and predict human performance as it interacts with the other system components and impacts on C^2 system effectiveness. These efforts are directed at both operational and advanced C^2 systems, which are described below.

Operational C^2 Systems

This part of the HPC^2 program calls for the measurement of human performance and user/computer interactions in representative operational systems. The performance of subsystem operators as well as higher-level decision makers will be assessed. To ensure maximum applicability of these data, evaluations will be conducted within air, surface, submarine, and fleet contexts.

1. Tasks:

a. Devise techniques for unobtrusively measuring critical human performance in the operational environment.

b. Develop methodologies for the measurement of team performance during fleet exercises and analyze implications for team composition.

c. Identify measures of effectiveness for C^2 systems that incorporate human information processing and decision making.

d. Assess and document user performance in the Navy Command and Control Systems (NCCS); develop training packages and user aids as appropriate.

e. Investigate decision maker performance for the Battle Group ASWC during anti-submarine warfare coordination missions.

f. Analyze human performance issues in over-the-horizon targeting.

g. Investigate NTDS/AEGIS operator performance.

h. Study impact of information handling, editing, and composition aids (word processing) on decision-maker performance.

2. Testbeds

a. NPRDC: System Simulation Facility.

b. Surface systems: Fleet Combat Direction Systems Support Activity (FCDSSA); ASW School.

c. Submarine systems: Commander, Submarine Force, U.S. Pacific Fleet (COMSUBPAC); Naval Submarine Training Center, Pacific Detachment (NSTCPAC).

d. Task force/fleet systems: Commander-in-Chief, U.S. Pacific Fleet (CINCPACFLT); Chief of Naval Operations, Navy WWMCCS Command Center (CNOFLAGPLOT)

Advanced C^2 Systems

This effort investigates user/decision maker performance on prototype systems in simulated but realistic C^2 environments. In this way, major deficiencies in system function and in the user interface may be identified and corrected relatively early in the development process. There is also the opportunity for the validation or reconfiguration of systems that are about to be deployed.

1. Tasks:

a. Implement techniques for human performance measurement in new C^2 technologies; develop guidelines to integrate such measurement into new systems.

b. Devise techniques for controlling stimulus events during engagement simulations.

c. Develop scenarios and engagement simulators to support human performance analyses.

d. Investigate the impact of large-group display technology on human performance in the C^2 environment.

e. Determine the effect of automatic situation assessment on decision performance.

f. Conduct research on the utility of split-screen display technology.

g. Explore the effectiveness of advanced teleconferencing and communications networks on decision performance.

2. Testbeds--The specialized requirements and prototype nature of advanced C^2 systems restrict the availability of testbed facilities. However, the Advanced Command and Control Architectural Testbed at the Naval Ocean Systems Center has been designed to meet these requirements and is available to the HPC^2 program.

3. Products--These will consist primarily of data and analyses in the form of technical reports that describe the performance of user/decision makers in C^2 systems. Emphasis will be given to estimating the impact of such performance on overall C^2 system effectiveness.

The results are expected to provide the basis for system modifications and for the establishment of appropriate manpower and training requirements. Where feasible, the HPC^2 program will also develop small-scale training packages and user aids to remedy observed deficiencies. In all cases, the efforts will yield valuable data that will further enable the definition of critical human performance research issues.

4. Consumers--This effort serves the operational commands by its quantification of human performance and documentation of existing deficiencies. This is a necessary prelude to enable successful redesigns and retrofits to deployed systems. Planning and procurement agencies, such as NAVSEA and NAVELEX, will utilize the analyses and human performance data in the evaluation of future C^2 systems.

Objective: To provide for the systmatic application of human performance technology throughout the C^2 life cycle

In addition to the R&D efforts discussed above, the HPC^2 program maintains another, more pervasive goal of applying human performance technology throughout the life cycle of C^2 systems. Here, the program serves as a human performance consultant to C^2 system designers, developers, and users. As requested, the program would, for example, provide design guidelines for a new C^2 system, evaluate the user interface for a prototype technology, or troubleshoot an existing system or training regimen. Most importantly, this consultation function is maintained at all stages in the system development and utilization cycle.

To realize this objective, it is essential to maintain close contact with the various agencies that are responsible for C^2 system development, acquisition, and deployment. Working relationships have already been established with DoD, OP-94, NAVELEX, various Navy laboratories, and the operational community.

Beyond this role as consultant, the HPC^2 program is responsible for identifying and communicating underlying principles of human performance and decision making relating to C^2 systems. By providing human performance guidelines and functional specifications for C^2 system design, the program can make a valuable contribution to improved system effectiveness. The accomplishment of this objective depends critically on the technical achievements of the other elements of the HPC^2 research and development program.

1. Tasks--The precise projection of tasks is difficult at this date; however, some representative projects are given below:

a. Identify human information-processing requirements for ACDS, SUBACS, and proposed sensor and weapons employment systems.

b. Consult with technology designers (in Navy laboratories) regarding the information requirements for C^2 operations.

c. Evaluate user-computer interface of conceptual and prototype C^2 technologies.

d. Respond to the needs of operational commands to improve user/decision-maker performance with existing C^2 systems.

e. Ensure that C^2 system test and evaluation plans provide for the measurement of human performance.

f. Assist acquisition managers to ensure proper contractor efforts on the human performance aspects of C^2 design.

g. Derive human performance guidelines and functional specifications for the use of C^2 system designers.

2. Products--The primary results of this effort will be informal recommendations presented via memoranda and briefings. Technical reports will be issued for the more extensive analyses that provide system design guidelines and functional specifications. Demonstrations will be provided for prototype man-computer interface designs.

Another output is the short-term fix to specific problems. While the fighting of isolated fires is not the preferred mode, it is recognized that "quick and dirty" solutions are often necessary--especially when the alternative is a total lack of human performance input.

3. Consumers--This effort will be useful to many design groups and operational units, but NAVSEA and NAVELEX will continue to be the primary consumers. Representatives of these organizations have reiterated that their single but most urgent need is for system requirements stated from the user's point of view.

ORGANIZATIONAL RELATIONSHIPS AND IMPLEMENTATION

The C^2 community in the Department of Defense is a broad one, involving a wide variety of organizations and interests. This stems from the critical role of C^2 and the requisite complex relationships among hardware, software, and human users. The HPC^2 program focuses on people-related R&D as it contributes to the C^2 enterprise and, accordingly, maintains close contact with the major centers of C^2 R&D and coordination.

Program Sponsors and Coordinator

The Defense Communications Agency, through the Command and Control Technical Center (CCTC), designs and evaluates computer system architecture and software for those systems supporting the Joint Chiefs of Staff. These systems play an important role in communicating information about the readiness and disposition of U.S. military forces and in determining priorities for employment of those forces. CCTC officials support the formulation of an NPRDC plan of research to provide system designers with user-oriented system specifications.

CNO has recognized the importance of C^2 technology by establishing within his staff OP-94 (Command, Control, and Communications), which has central coordinating responsibility for all Navy C^2 matters. The Chief Scientist of OP-94 has expressed his interest in the establishment of an HPC^2 program at NPRDC; he affirms the importance to successful C^2 system development of specifying human information-processing characteristics and limitations.

NAVELEX is the focus for equipment specification and component interface design in Navy C^2 installations. This work is directed primarily by ELEX-06, but additional coordination is required with ship, aircraft, and command center architecture in the Naval Sea Systems Command and in the Naval Facilities Command. The HPC^2 staff provides support to ELEX-06 through participation as technical and scientific advisors to C^2 design teams and committees, such as the Naval Warfare Advisory Group.

Scientific Base

The Office of Naval Research (ONR) and the Defense Advanced Research Projects Agency (DARPA) actively support academic and industrial research in the HPC^2 area through contracts and symposia that emphasize psychological processes and automated information processing techniques. This support serves to maintain a scientific base for future application to military systems. In contrast to these agencies, the HPC^2 program at NPRDC performs in in-house R&D in both fundamental and applied aspects of people-related problems in C^2. A strong emphasis is given to providing quick response to the immediate needs of the operational community, the training community, and those commands responsible for C^2 requirements and definition.

Defense Laboratories

The Army and the Air Force are both concerned with the human engineering aspects of C^2 systems. The Army Research Institute conducts applied research on human performance in combat information systems within two of its technical areas: battlefield information systems and systems integration and command/control. In addition, the Army Human Engineering Laboratory conducts human factors research relevant to C^2 systems design. The Army Command and General Staff College at Fort Leavenworth and the Army Training and Doctrine Command (TRADOC) pursue programs in training tactical skills and in tactic evaluations. The Air Force Office of Scientific Research sponsors a variety of basic and applied research, much of which relates to C^2 system issues. The Aerospace Medical Research Laboratory is engaged in biopsychological, human factors, and human performance research through its Human Engineering Division. The Air Force Human Resources Laboratory has responsibility for work in human performance in C^2 systems through its Advanced Systems Division.

Several Navy laboratories develop and design hardware and software for Navy combat information systems. These include the Naval Ocean Systems Center (NOSC) and the Naval Undersea Systems Center (NUSC). NOSC is the lead laboratory for engineering design of Navy C^2 systems and operates the Advanced Command and Control Architectural Testbed (ACCAT) under the sponsorship of NAVELEX. The purpose of ACCAT is to provide a secure facility for the test and evaluation of new C^2 technologies that have potential for future Navy applications. The current focus in ACCAT is on user-oriented programming languages, advanced display techniques, data base development, natural language query systems, and decision-aiding algorithms. Other Navy laboratories with related interests include the Naval Weapons Center (NWC) and the Naval Air Development Center (NADC).

Other Related Navy Agencies

The Naval Postgraduate School (NPS) has established a curriculum in C^2 technology that offers young military officers an opportunity to conduct research leading to the Master's degree. This program is interdisciplinary and centers around the departments of electrical engineering, computer science, and operations research.

The Naval War College is modernizing its tactical simulation facilities for training senior officers in naval warfare. This project involves a multipurpose interactive and sophisticated war gaming system; user-oriented features are emphasized.

Implementation

The tasks, products, and consumers for the work efforts of the HPC^2 program were described in the previous section. Figure C-1 gives an overall, functional view. It represents an R&D approach that weds information from users and research efforts into a process of integrated development. This contrasts with the sole reliance on uncoordinated technological progress that, in the past, has not provided the military with integrated system design. The center column represents the HPC^2 program and highlights those functions that interact with mission sponsors, development agencies, and R&D centers. The left-hand column represents hardware/software development and the test and evaluation of candidate systems. The right-hand column gives the manpower, personnel, and training system functions that benefit from the products of the HPC^2 program. Thus, the products of the program are used in four ways:

1. To provide specifications and evaluations to hardware/software system designers.

2. To provide information to manpower, personnel, and training system planners for the design of manpower support systems.

3. To provide C^2 system users with tactical decision and training aids.

4. To provide feedback for further R&D efforts within the HPC^2 program itself.

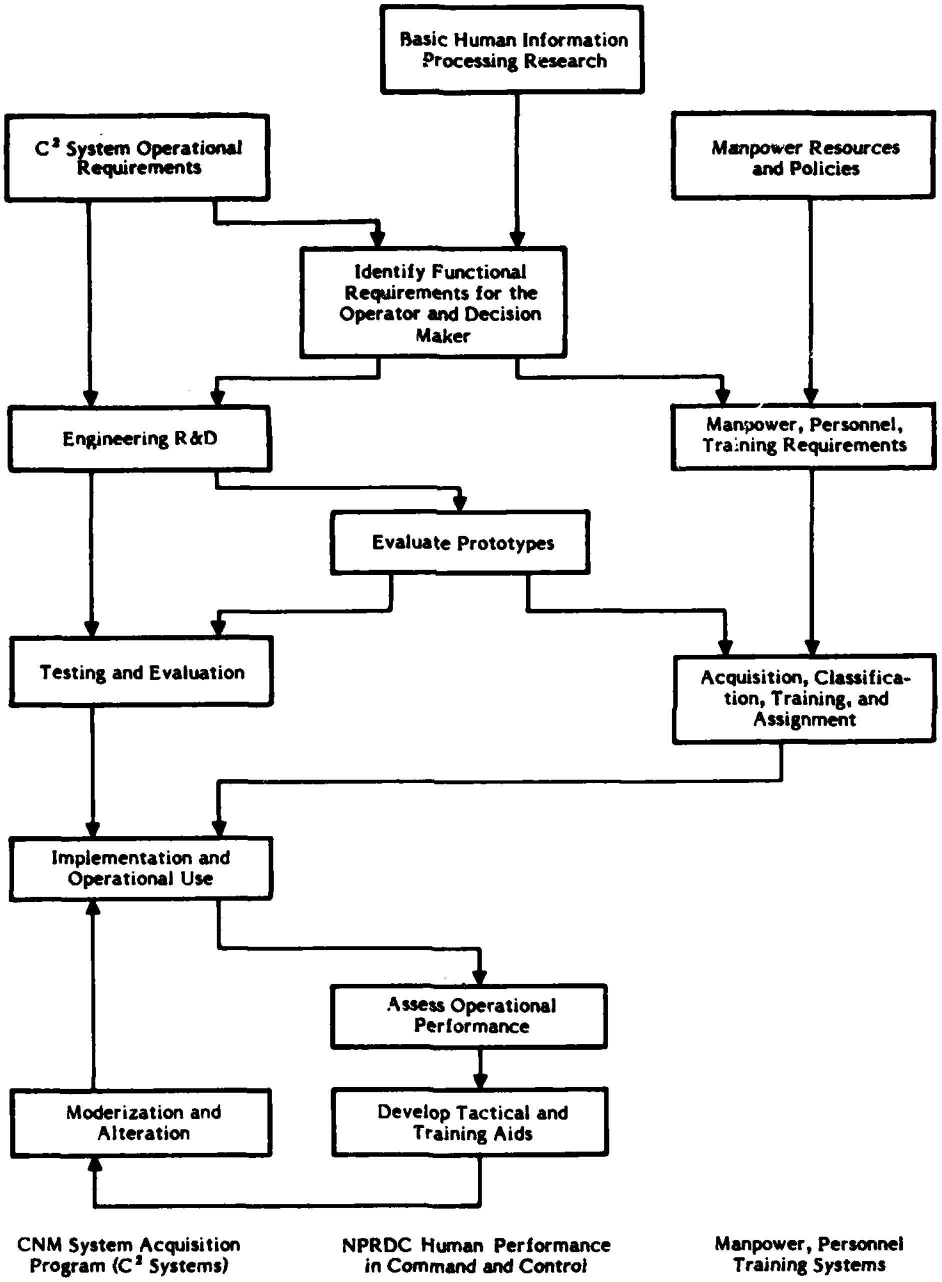

Figure C-1. Functional view of the HPC² program.

REQUIRED RESOURCES

Staffing

Table C-1 outlines the projected staffing requirements for the HPC^2 program through FY87. The professional staff is interdisciplinary and includes expertise in cognitive psychology, human engineering, computer science, and operations research. The research psychologists emphasize skills in cognitive psychology, mathematical modeling, experimental design, physiological psychology, human engineering, and computer programming. The psychological research assistants will be selected on the basis of a strong background in quantitative behavioral research. The computer specialist position requires experience with mini/microcomputers and an interest in behavioral research and artificial intelligence. The military liaison should have experience in C^2 systems, operations research, or related disciplines.

Table C-1

Staffing Requirements

Position	FY83	FY84	FY85	FY86	FY87
Research Psychologists (GS-13)	1	1	1	1	1
Research Psychologists (GS-11/12)	4	5	5	5	5
Research Assistants (GS-7/9)	1	1	2	2	2
Computer Specialists (GS-11/12)	1	0	0	1	1
Military Staff (MSC, O-3/4)	0	1	1	1	1
Secretary (GS-4/5)	1	1	1	1	1
Total	8	9	10	11	11

Funding

Table C-2 shows the projected costs for the HPC^2 program through FY87. Contract support will be used as required to augment the technical capabilities and workload of the professional staff. Such support will serve primarily to assemble and deliver specific reports and software products that emerge from the results of the program's R&D efforts.

Table C-2

Projected Costs

Item	FY83	FY84	FY95	FY86	FY87
Staff	600	750	850	1,025	1,025
Contract	75	75	100	150	150
Supplies, travel, equipment	100	125	150	175	150
Total	775	950	1,100	1,350	1,325

Note. Costs are in thousands of 1982 dollars.

Space Requirements

Suitable office space is required for the professional staff and its clerical support. Existing laboratory space plus the proposed System Simulation Facility will be adequate to support the proposed program.

Computer and Facilities Support

1. Field research and user aids. The HPC^2 program calls for the collection of data from operational users in their C^2 environments and the development of user aids and training modules for immediate fleet application. The portable stand-alone minicomputer with graphics capability is the device of choice for these efforts. This type of intelligent, distributed processor is expected to become increasingly important in Navy C^2 systems. There will continue to be a need for such processors in the HPC^2 program.

2. On-site simulation and research. A substantial effort in the HPC^2 program is the study of the man-computer interface in C^2 systems. To explore critical relationships at this interface, there is a requirement for a flexible, computer-based research facility that permits system simulation and the assessment of the performance of varying man-computer configurations. The NPRDC System Simulation Facility will provide this capability.

3. Advanced systems research. A facility is required to support human performance R&D with advanced C^2 prototype technologies. Computers, displays, and controls are needed to implement the technologies, and access to realistic, dynamic Navy C^2 data is required. The Advanced Command and Control Architectural Testbed at NOSC provides these capabilities and will be available to support the human performance program.

4. Data analysis. Computer resources also will be required to support statistical analyses of the data collection by the HPC^2 program. The computer facilities at NPRDC can satisfy these requirements.

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